MULTISPECTRAL ANALYSIS OF MARE DEPOSITS IN SOUTH POLE/AITKEN BASIN. R. Aileen Yingst and James W. Head, Dept. Geological Sciences, Brown University, Providence, RI 02912 USA; yingst@pggipl.geo.brown.edu.

Background: Because only a small fraction of the Moon's surface is covered in volcanic (mare) material, the Moon provides us with a window into the early stages of the formation of secondary crust (derived from partial melting of the mantle) [1]. To model this formation, however, it is vital to understand the sequence of events or processes that led to magma transport and eruption. It has been hypothesized that mare emplacement was controlled by propagation of dikes driven by the overpressurization of diapir-like source regions stalled under crustal columns of varying height [2,3,4]. Analyses of the characteristics of lava ponds estimated to be individual eruptive episodes in the South Pole/Aitken, Orientale/Mendel-Rydberg and Smythii-Marginis basins using Clementine [5], Lunar Orbiter and Zond data have provided evidence that supports this theory [6,7,8]. The availability of multispectral data provided by the Clementine mission provides us with an opportunity to better constrain our estimates of the characteristics of single eruptive episodes using variations in mare soil composition. Thus we may further model the aspects of lunar magma ascent and extrusion. Here, we report on an analysis of the compositional characteristics for 21 mare deposits in the South Pole/Aitken (SPA) basin, and investigate implications for typical lunar eruptive episode.

Approach: To understand the mechanisms responsible for the emplacement of mare material it is crucial to isolate basic commonalities for single lunar eruptive episodes. Using this characterization, it should be possible to reconstruct the conditions of transport and eruption to explore the nature of source regions, and to deconvolve the various changes in eruption style spatially and stratigraphically. It is difficult, however, to isolate and examine a single flow or eruptive event in the large nearside maria because of their inherent complexity (multiple overlapping flows, wide age variations, etc.) [8]. We have adopted an approach in which analysis focussed on statistically significant clusters of discrete mare deposits (ponds) in the highlands on the lunar limbs and farside. Ponds were originally chosen as good candidates for estimates of single eruptive events based upon homogeneity in albedo and crater density, as well as lack of geomorphological evidence for multiple eruptive events [6,7,8]. As a next step, we report here our endeavors to confirm the boundaries of individual flows and eruptive units on the basis of spectral signature variations, and begin global compositional comparison, by examining the multispectral data returned by the Clementine spacecraft. It should be noted that there is a phase angle shift such that those images at phase angles not equal to 30° are shifted to redder wavelengths as phase angle increases [9]. In addition, this wavelength shift is not currently well constrained for images taken at below ~20° phase angle [9]. Thus, in order to be more certain of our deposit characterization, analysis was limited to those ponds lying between 30° - 50° phase angle with respect to the spacecraft. Out of the ponds initially examined on the lunar limbs and farside, 21 ponds in northern SPA fit this criterion.

UVVIS Data and Results: Twenty-one SPA ponds were examined in terms of existence and type of basaltic signature, as well as spectral variations that might indicate multiple flows. It was found that: (1) 19 ponds originally mapped as mare basalt (90% of those studied) show a spectral signature distinctive to mare basalt; (2) 14 ponds (all but one of the 15 ponds estimated to be good candidates for single eruptive episodes) show a relatively homogeneous spectral signature; and (3) all 21 deposits studied had soils that appear to be only a few percent bluer than the surrounding highlands, suggesting that none of the ponds have a high titanium content.

Basalt Determination. Because the best images previously available for many areas of SPA were poorer than 300 m resolution, and in some cases were taken at a highly oblique angle, determination of the basaltic nature of some deposits was ambiguous [e.g. 10]. Using multispectral data, however, we observe that 19 out of 21 ponds mapped as basalt [11,12] have soils that display a basaltic spectral signature (a relatively short wavelength 1µm absorption band). For example, Figures 1 and 2 show a 0.75 µm wavelength (1) and 0.75/0.95 µm wavelength (2) image of the south pond in Apollo basin. Figure 1 approximates the lower reflectance of the deposit, while Figure 2 shows those areas that have a strong absorption band around 1µm as brighter than regions that do not. Not only do many of the fresher craters inside the pond show ejecta containing mafic-rich (brighter) material, the entire pond has a higher reflectance than surrounding regions. The boundary displayed in Figure 2 almost precisely matches the albedo boundary seen in original Lunar Orbiter images. This suggests that original estimates of pond areas and volumes [8] represent the correct bounding areas for these basalts.

Multispectral Heterogeneities. Image cubes were created for the study areas such that the 0.75/0.415 µm and 0.415/0.75 ratios (sensitive to continuum slope variations) were assigned the red and blue channels respectively, and the 0.75/0.95 µm ratio (yielding a first-order estimate of the strength of the 1 µm absorption band associated with mafic-rich soils) was assigned the green channel [e.g. 13]. These image cubes were examined for indications of distinct spectral regions within the pond confines. Out of 15 ponds originally estimated to be good candidates for individual eruptive episodes, only one (within Crocco crater) displayed heterogeneities in its spectral signature across the pond area that may be interpreted as indicative of multiple flows. These results are consistent with those obtained using Lunar Orbiter and Zond images [8].

Preliminary Global Comparison. The slope of the visible continuum of mature mare soils is linked to TiO_2 content in that spectra of Ti-rich soils exhibit a flatter or "bluer" slope at visible wavelengths [14]. The SPA highland regions are relatively red spectrally (showing a strong continuum slope) [13]. Preliminary assessment of the overall reflectance associated with the mare deposits examined in this study suggests that these deposits are only a few percent bluer than the surrounding highlands. This implies that the mature mare soils associated with these ponds are not Ti-rich.

Conclusions: Analysis of 21 mare deposits within SPA corroborate original estimates of characteristics of lunar single eruptive episodes [6,7,8], providing further evidence to support a first-order global hypothesis for lunar magma transport and eruption [2,3,4]. Specifically, Lunar Orbiter albedo boundaries show an extremely high correlation to Clementine multispectral boundaries, so that the extremely large estimated pond areas and volumes based on albedo boundaries should be essentially correct. This is consistent with a magma transport model in which reservoirs stalled under a boundary defined by the lunar highland crust propagate dikes under great pressure, yielding high effusion-rate eruptions and thus large volumes per event [2,8]. In addition, we have added confidence to original estimates of single eruptive volumes in that we have shown that those ponds estimated to be individual eruptive events [8] have a relatively homogeneous multispectral signature. Finally, preliminary global comparisons of the relative "blueness" of mare soils suggest that, with the possible exception of some Apollo mare deposits [15], high-TiO_2 mare soils may be localized to the lunar nearside. This implies either that different reservoirs were available on the farside with respect to the nearside, or the tapping of high-TiO_2 reservoirs is somehow hindered on the farside. Future efforts will focus on combining this data with appropriate crater-frequency data, thus providing a stratigraphic as well as a compositional profile of mare deposits on the lunar limbs and farside. These are the first steps in understanding the fundamental differences between near- and farside lunar volcanism.

References: [1] S. R. Taylor, *Tectonophysics 161*, 147, 1989. [2] J. Head and L. Wilson, *G&CA*, *56*, 2155, 1992. [3] J. Head and L. Wilson, *PSS, 41*, 719, 1994. [4] L. Wilson and J. Head, *JGR*, *86*, 2971, 1981. [5] M. Zuber, *et al.*, *Science*, *266*, 1839, 1994. [6] R. A. Yingst and J. W. Head, *LPSC 26*, 1539, 1995. [7] R. A. Yingst and J. W. Head, *LPSC 27*, 1479, 1996. [8] R. A. Yingst and J. W. Head, Volumes of lunar lava ponds in South Pole-Aitken and Orientale basins: Implications for eruption conditions, transport mechanisms, and magma source regions, *JGR*, in review. [9] S. Nozette *et al.*, *Science 266*, 1835, 1994. [10] D. Wilhelms, *USGS PP-1348*, 302 pp, 1987. [11] D. E. Stuart-Alexander, *USGS Map I-1047*, 1978. [12] D. Wilhelms et al., *USGS Map I-1162*, 1979. [13] M. J. S. Belton *et al.*, *Science 255*, 570, 1992. [14] M. Charette *et al.*, *JGR 79*, 1605, 1974. [15] R. Greeley, *et al.*, *JGR 98*, 17,183, 1993.

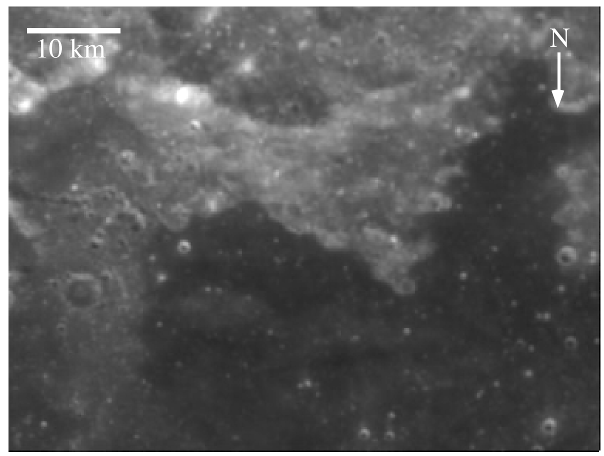

Figure 1. Clementine image of southern mare deposit in Apollo basin at 0.75 µm.

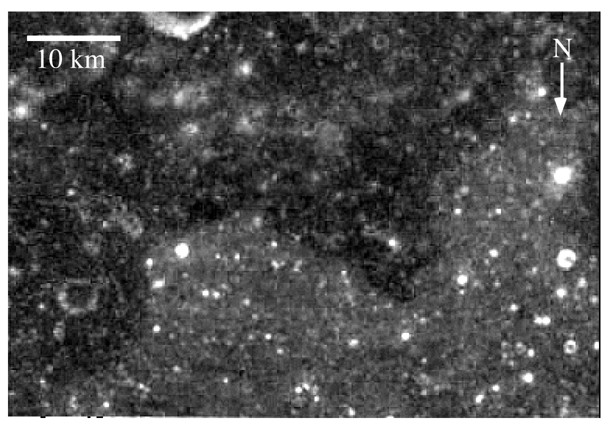

Figure 2. Clementine image of southern mare deposit in Apollo basin at 0.75 / 0.95 µm.